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TAKING THE PULSE OF OUR PLANET FROM SPACE

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Convolutional neural networks for soil organic carbon mapping from Sentinel-2 satellite imagery; a case study in Bavaria state

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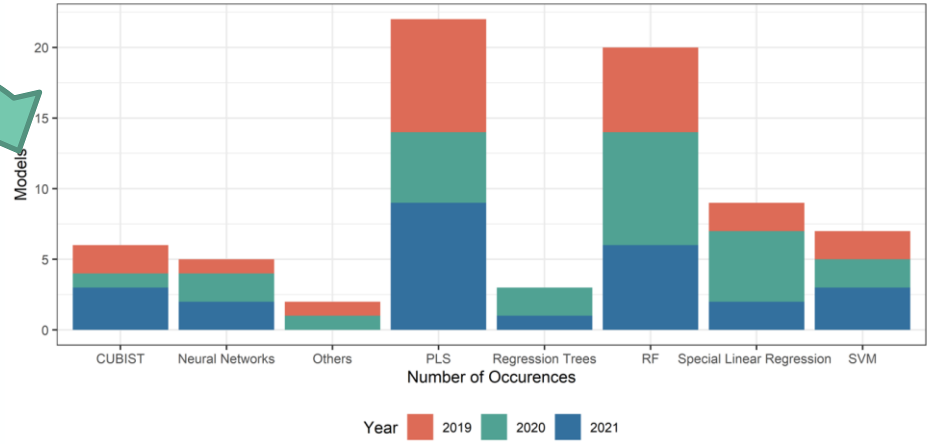
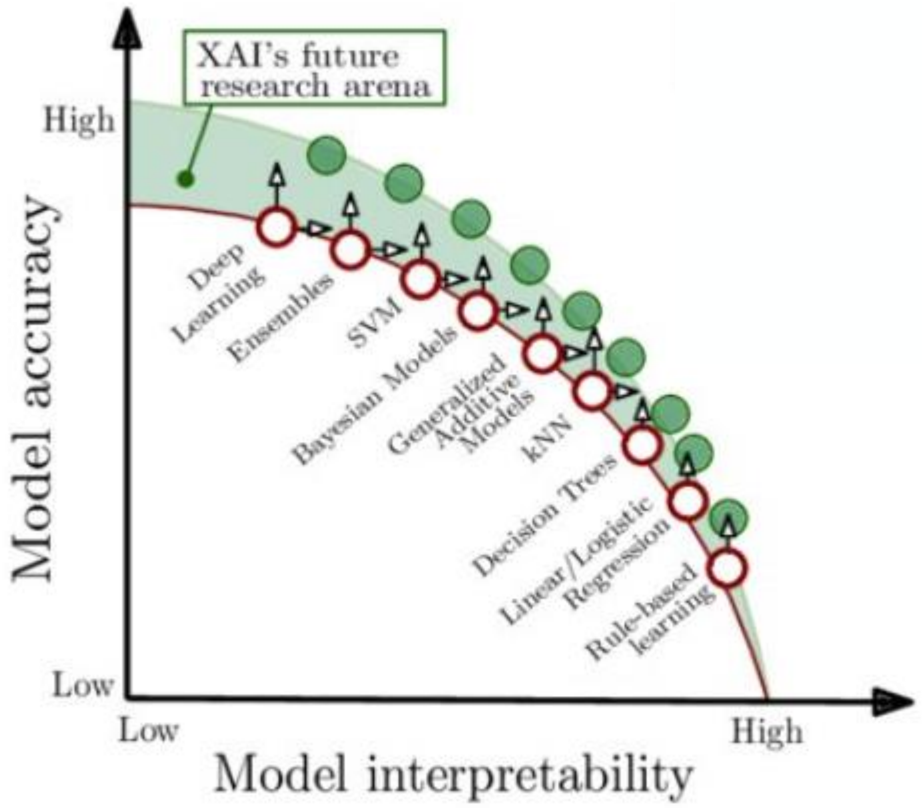
The rationale



(https://doi.org/10.3390/rs13214439)

- PLS and Random Forest are certainly the most popular ML algorithms;
- In 2015 has been applied for first time DL architectures for soil property prediction;
- There is an increase in the use of Neural Networks (e.g., DL)

Pillars that should drive the DL architecture development



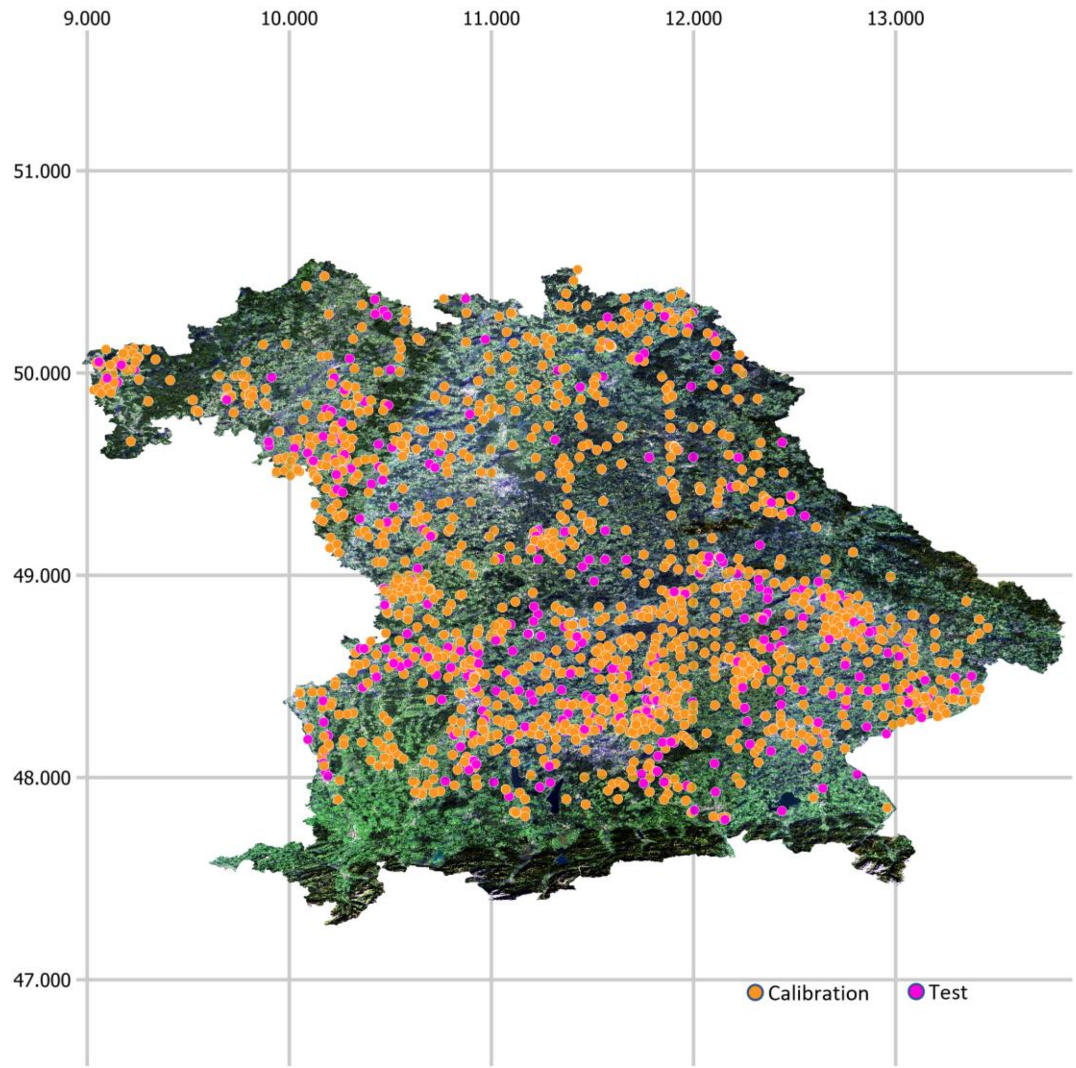
(dx.doi.org/10.1016/j.inffus.2019.12.012)

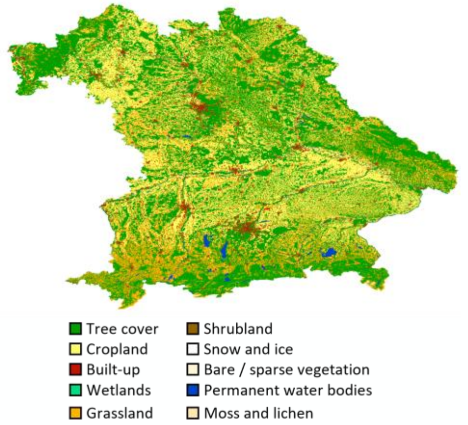
- DL is not a **panacea**
- **Move from black to glass box models (XAI);** Explainability is important for debugging AI models and making informed decisions (<20% present explainability or mentioned it's importance)

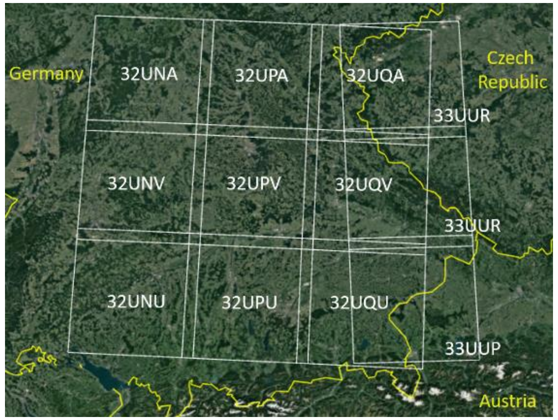
Interpretability: Post-hoc explainability techniques; Interpretability-driven model designs

Accuracy: Hybrid modelling approaches; New explainability-preserving modelling approaches

Study area and data



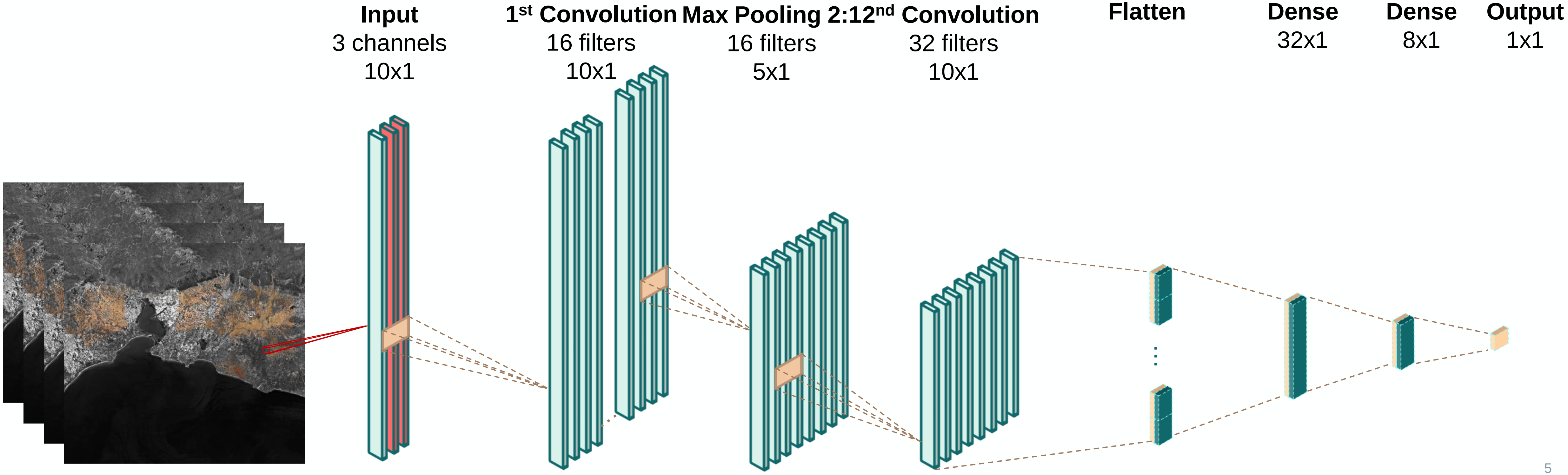




- **1933 topsoil samples** (LUCAS, Bavarian Environmental Agency and State Research Center for Agriculture); SOC content ranges from 0.26 to 180 g · kg^{-1}
- **Sentinel-2** data (exc. 60m bands) from 12 tiles; cloud coverage <80%; range from 2018-2020; i) spring; ii) spring-autumn; and iii) full months
- Processing with **Soil Composite Mapping Processor** by DLR

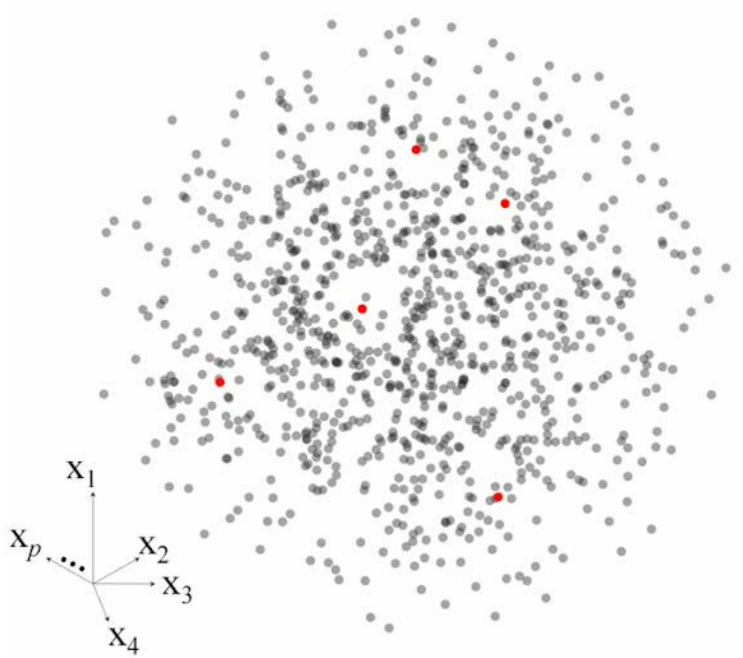
CNN architecture

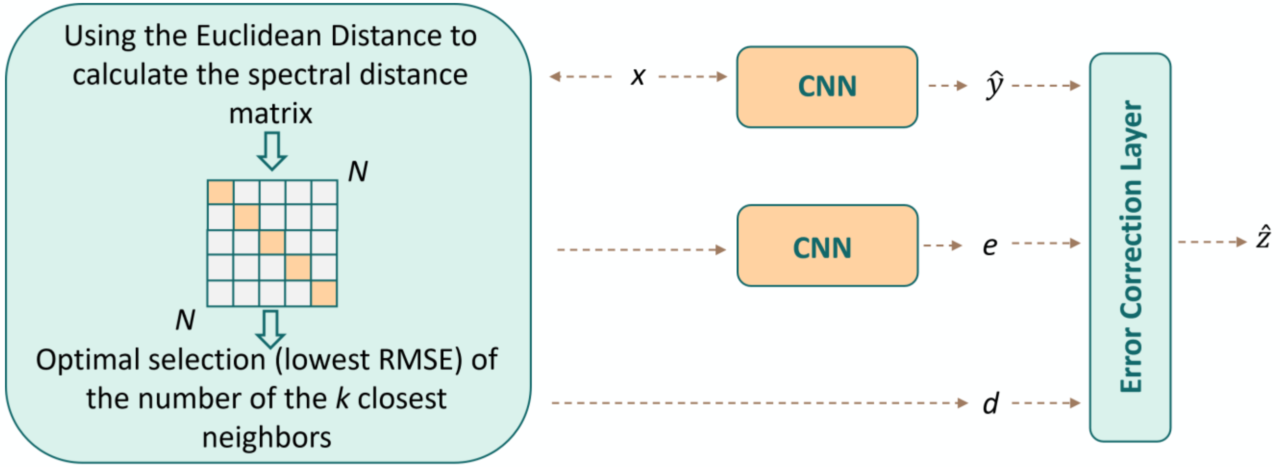
- **Shallow deep learning** architecture able to handle multispectral data, supporting also multi-output predictions;
- Exploits the **complementary information** contained from multiple spectral sources (no need to find the best pre-treatment);
- Address the issue of **interpretability;**
- Evaluate the inclusion of spectral indices (e.g., NDVI, NBR2 etc.) as additional predictors (**CNN with indices**)



Local error correction mechanism

- **Local error correction mechanism**, where information from a global model is used to localize multiple models (utilize the k ∈ [10, 200] nearest neighbors)
- Spectral distance calculation and closest neighbor selection by Euclidean Distance

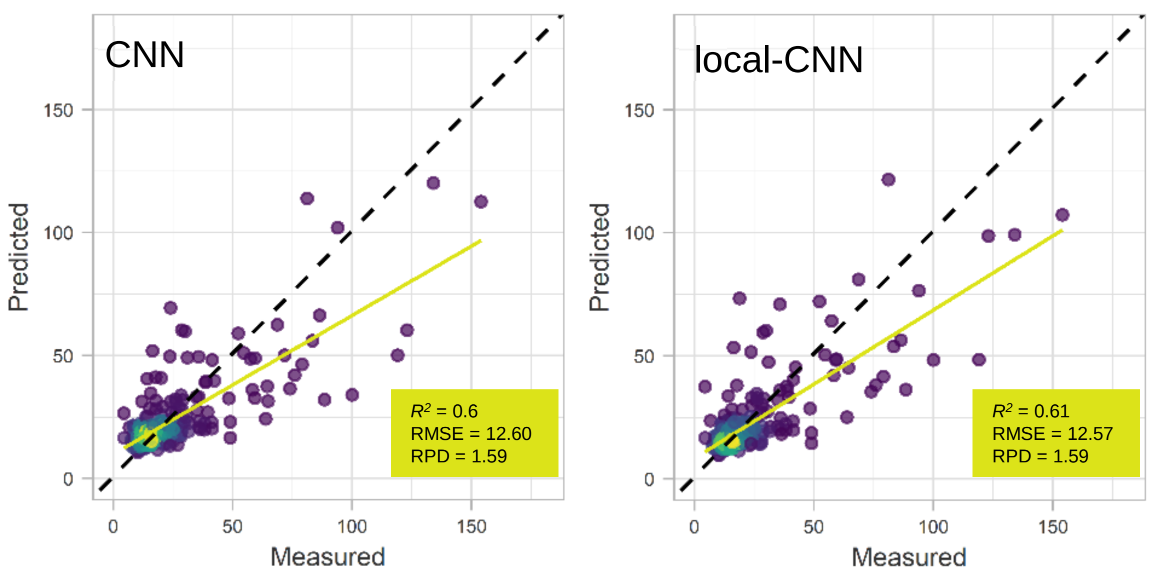




Predictive performance

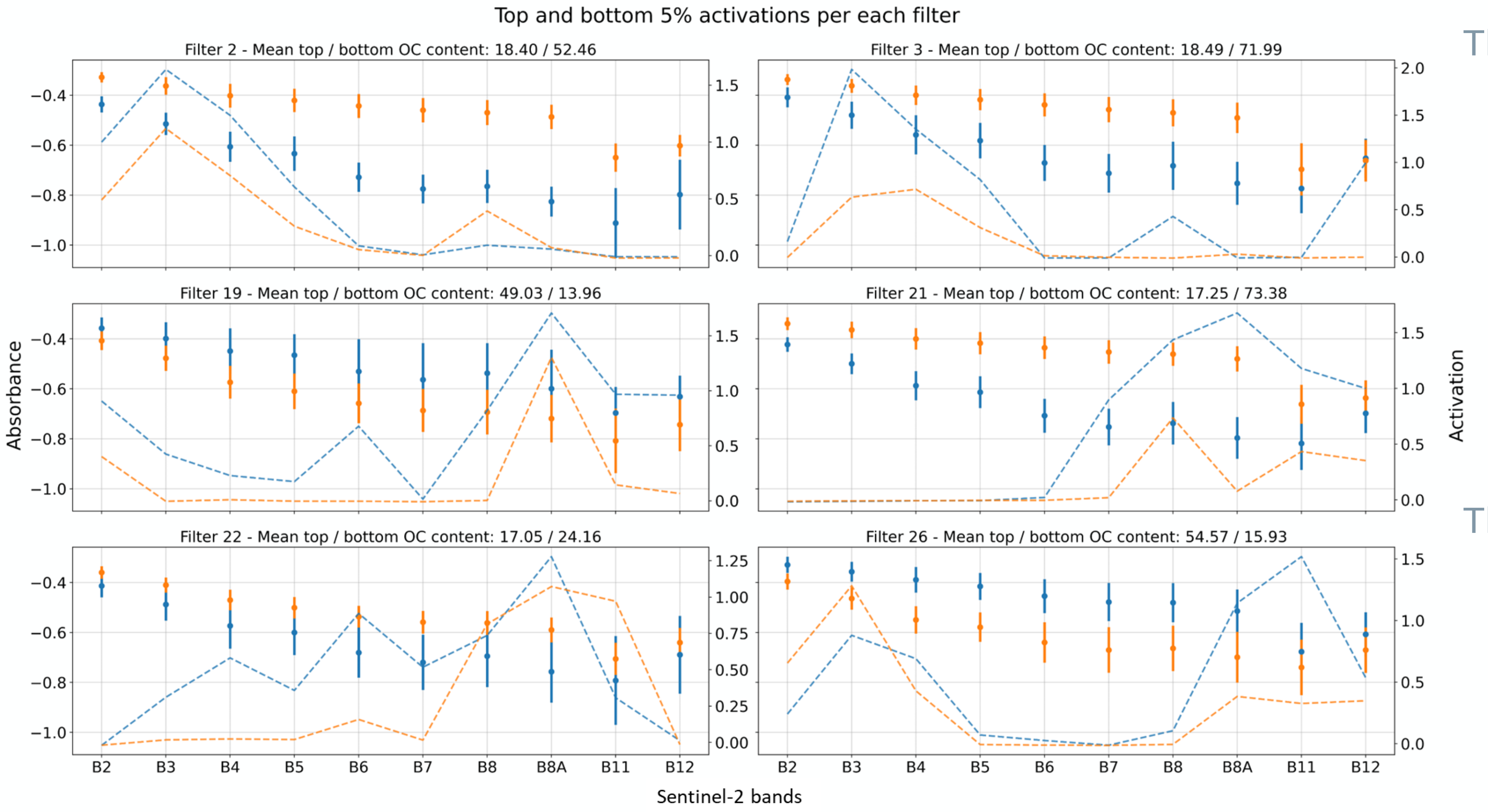
Composite	CNN				CNN with indices		
	RMSE	R^2	RPD		RMSE	R^2	RPD
Full_SRC	12.65	0.60	1.58		12.93	0.58	1.52
Autumn_SRC	12.84	0.59	1.56		13.27	0.59	1.51
Spring_SRC	**12.60**	**0.60**	**1.59**		13.55	0.54	1.48

Spring_SRC



- Best performance for the Spring soil reflectance composites (SRC)
- There is no need to include vegetation indices as additional spectral features in CNN;
- Statistical **marginal improvement (~1%)** due to the proposed **error-correction scheme;**
- The herein proposed **CNN scored significantly better** compared to current SOTA models for Sentinel-2 data (PLS: R^2=0.49, RMSE =13.76 g · kg^{-1}, RPD =1.4).

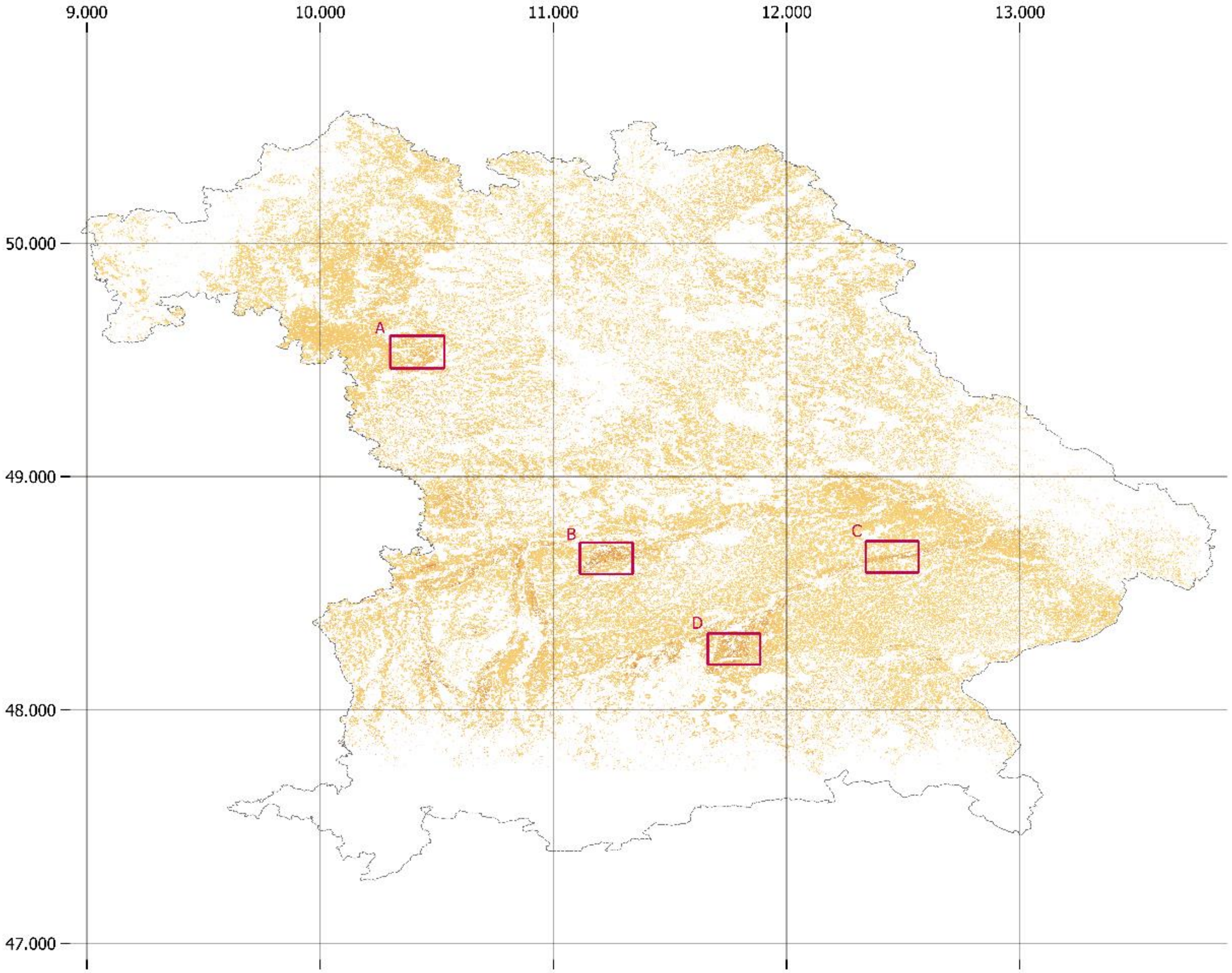
CNN interpretability



The **visible range**, and in particular the beginning of the spectrum. This may be attributed to **soil color** and the albedo of the sample which is influenced by the presence of organic matter

The **upper SWIR region**, where absorptions due to the presence of organic materials may also be found.

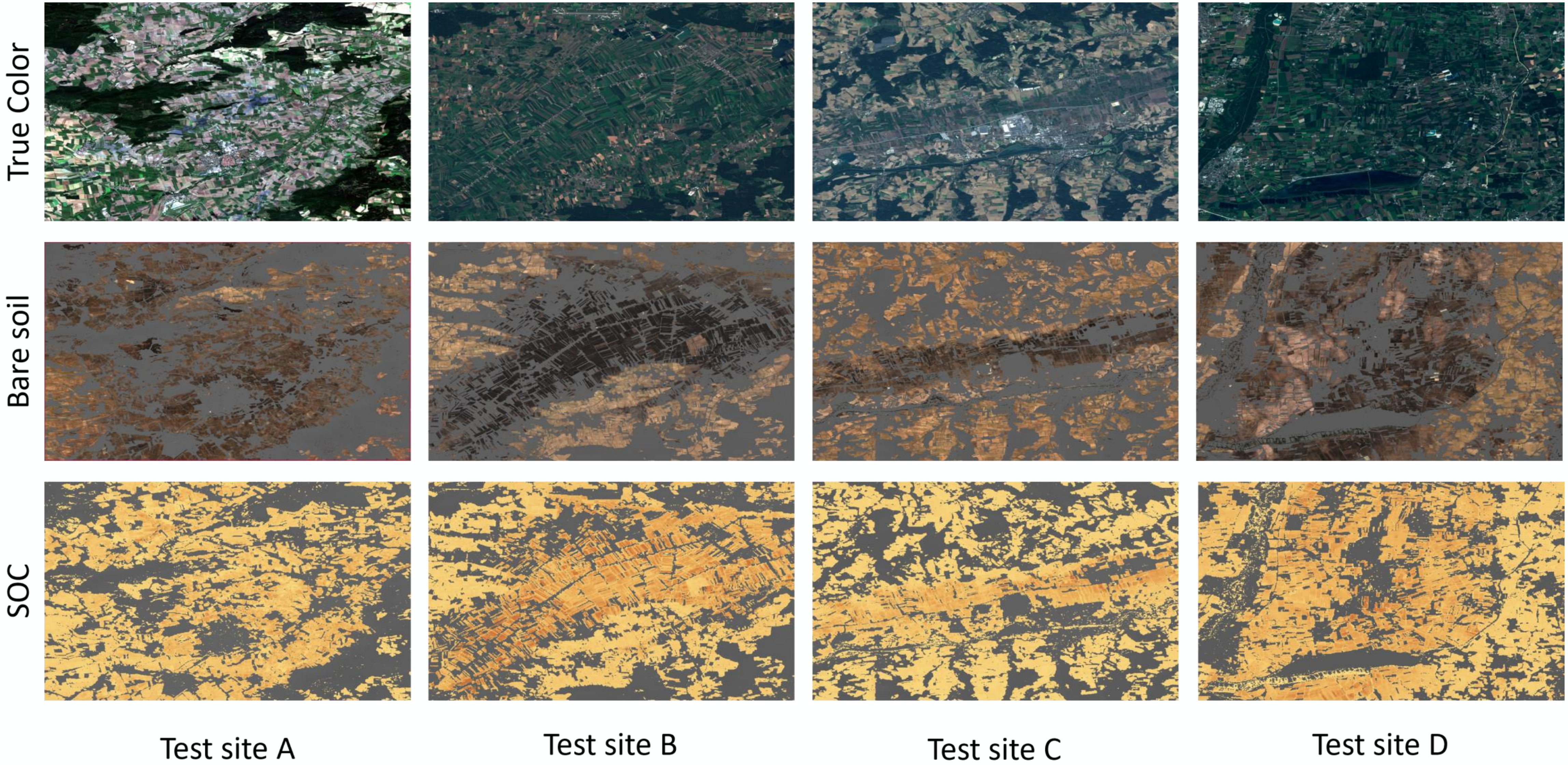
SOC map in Bavaria



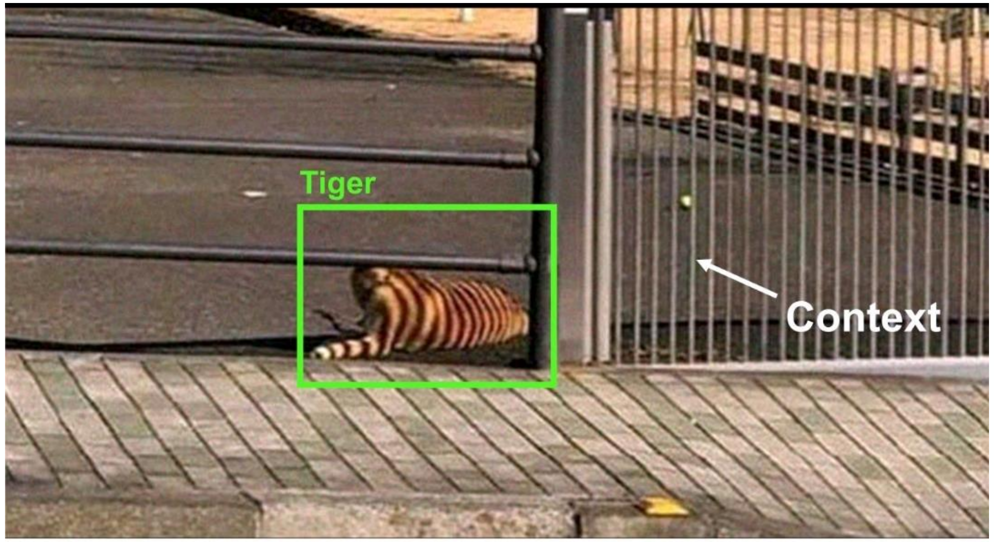
20% of the RoI recognized as exposed soils

Visually homogeneous predictions; free of any apparent artifacts

SOC map In Bavaria



Remarks and Suggestions



Conclusion

We developed for a first time a localized multichannel CNN able to handle Sentinel-2 data to predict soil properties

Future steps

Exploitation of additional information sources like the DEM and environmental covariates in a multi-branch approach;

Utilize both **geographical and spectral distance vectors** for neighbor selection.

Utilize **hyperspectral missions** (e.g., PRISMA, EnMAP) to leverage the benefits of the multi-input CNN model.

THANK YOU!

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